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Optimal Location of Unified Power Quality Conditioner in Distribution System for Power Quality Improvement

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ABSTRACT

The increased use of nonlinear loads in distribution system is increasing the distortion in the voltage and current waveforms. Moreover, the distribution systems are inherently unbalanced. This paper presents Cuckoo Optimization Algorithm (COA) based Unified Power Quality Conditioner (UPQC) allocation in three phase unbalanced distribution network. The performance of UPQC is studied in terms of minimization of load disturbance during fault condition in the test systems, % reduction of total harmonic distortion and individual harmonics, minimization of real power loss, decrease in voltage unbalance and increase in cost savings during normal operating condition. The performance of COA is compared with other soft computing techniques to get the better results, i.e., better voltage profile, the optimal location and optimal number of UPQCs.

Introduction

The deterioration of the secured level of power quality has gained significant attention in the past few years [1]. With the increase in use of advanced power electronics and computer controlled devices in distribution system, problems due to power quality events such as the voltage sag and swell, harmonics generation are increasing. Harmonics generations are becoming a grave concern in distribution system. Besides these, voltage sag–swells and power factor also add to the power quality problem at the utility side [2]. Moreover, many industries are demanding stricter power quality standards to diminish the harmonics generation and reactive powers consumed by the loads [3]. Simultaneously, the microprocessor-based controllers required for these industries are highly sensitive to the line voltage distortions [4].

In such conditions, usual power quality improvement equipments are proving to be inadequate for these sophisticated applications and this fact has drawn a great attention to the power engineers to develop dynamic and adjustable solutions to power quality problems. The compensating devices such as dynamic voltage restorer [5], uninterruptible power supplies [6] and active filters [7] are proposed to improve power quality. But, their capabilities are usually limited as they can only solve one or two power quality problems [8]. Recent research has shown that Unified Power Quality Conditioner (UPQC) can simultaneously fulfill different objectives, such as maintaining a sinusoidal voltage at the bus at which it is connected [8], maintaining voltage when there are voltage sags and swells in the system [9,10], eliminating harmonics in the source currents [4,11,12], voltage sag mitigation [13], load balancing [17] and power quality improvement [15–17]. UPQC is a flexible device, that comprises of shunt and series Active Power Filters (APFs), sharing a common dc link [18].

Many researchers have studied UPQC as an eventual solution to improve the power quality in electrical distribution system [19,20]. But due to high cost involved, the location of UPQC in distribution system has to be decided with great care and should preferably be solved as an optimization problem. The optimization of UPQC placement problem in a competitive environment comprises in the minimization of power losses, total harmonic distortion (THD) minimization, voltage profile improvement and unbalance reduction under normal and voltage sag conditions [21,22].

This paper presents a method based on Cuckoo Optimization Algorithm (COA) [23] to find optimal location of UPQC device considering THD, voltage profile improvement and power system losses. In fact, the optimal location of UPQC installation is found out by estimating the loss of load due to voltage sag for each probable location of UPQC. However, the location and type of the fault, which causes this voltage sag and load curtailment, has also been discussed in this paper by a rational approach. The proposed UPQC placement algorithm has been tested on 25-bus distribution system and IEEE 123 node test feeder. Some of the results are

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produced in this paper to establish the computational ability and robustness of the method.

Operation of UPQC for power quality improvement

The basic operating principles of UPQC are already established in open literature [9]. A schematic representation of three-phase four wire voltage source converter-based UPQC is shown in Fig. 1. The UPQC is made up of series APF and shunt APF. The shunt APF is usually connected across the loads to compensate for all current related problems, such as reactive power compensation, power factor improvement, current harmonic compensation, dc link voltage regulation and load unbalance compensation. The series APF is connected in series with a line through a three-phase series transformer [5]. It acts as a controlled voltage source and can compensate for all voltage related problems, such as voltage harmonics, flicker etc [19,24]. There by, UPQC reduces the load disturbance area to a normal operating zone by fault protection. It also mitigates voltage unbalance, voltage sag and reduces real power loss. In this paper, model of UPQC consisting of two inverters connected by a common dc storage capacitor, is used [8]. One of these inverters is used for series voltage insertion and the other is used for shunt current injection.

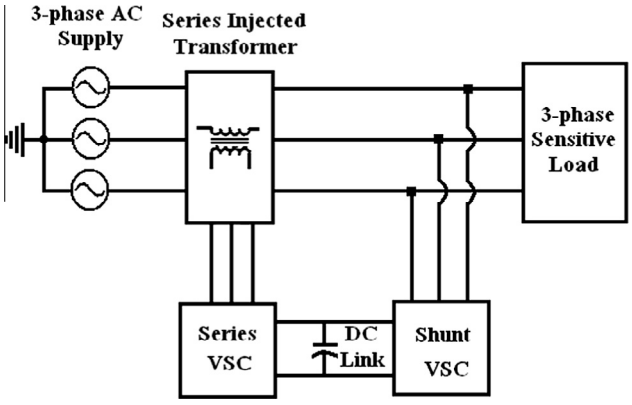

Fig. 1. Schematic representation of UPQC.

The brief description on operation of series inverter and shunt inverter are given below:

Fig. 2 shows the phasor diagram of voltage and current injections by series and shunt inverter of UPQC. The magnitude of injected voltage V_{se} by series inverter depends on maximum voltage sag to be mitigated [25].

During normal and voltage sag conditions, source voltage magnitudes are denoted by

$V_s = V_{S0}$ and $V_s = kV_{S0}$. In this paper, $k_{sag} = (1-k)$, p.u. sag in source voltage.

At any condition load voltage, $V_L = V_{S0} = V_s$.

Series voltage injection required to mitigate k_{sag} p.u. amount of voltage sag can calculated by,

$$V_{se} = \sqrt{V_L^2 + (kV_{S0})^2 - 2V_L(kV_{S0})\cos\delta} = V_s\sqrt{1 + k^2 - 2k\cos\delta} \quad (1)$$

By assuming a lossless UPQC, active power demanded by load can be expressed by active power drawn from source, i.e., $kV_sI_s = V_LI_L\cos\phi$, which yields the source current as,

$$I_s = I_L\cos\phi/k \quad (2)$$

where I_s and I_L are the compensated source-end current and load current respectively.

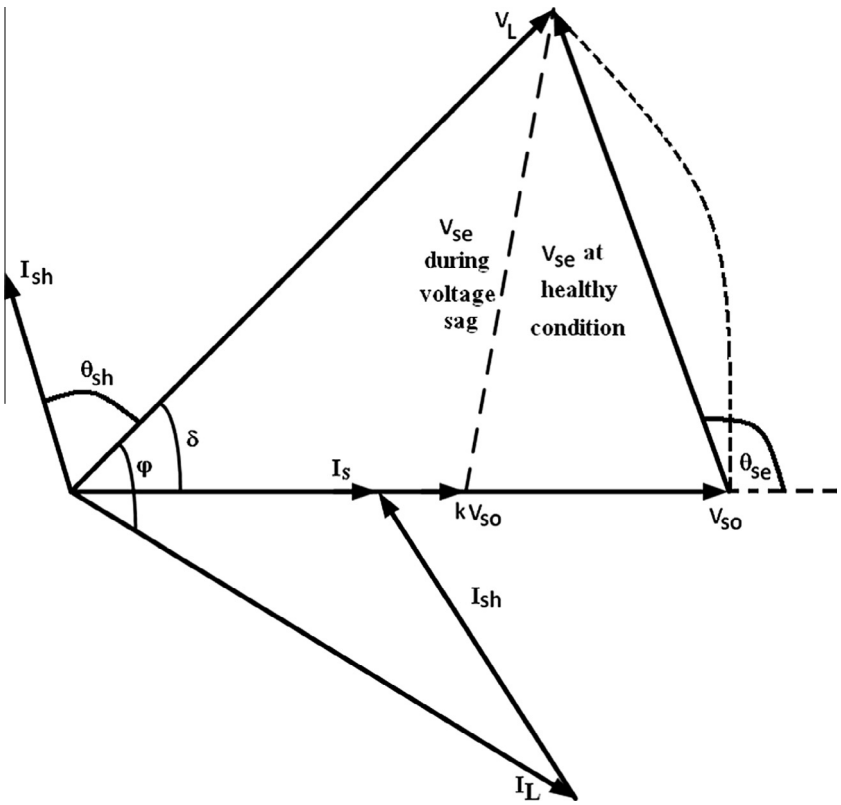

Fig. 2. Phasor diagram of shunt and series compensation of UPQC during normal and voltage sag condition.